THE

Evolution of Mine-Surveying Instruments.

BY

Dunbar D. Scott and Others.

Comprising the Original Paper of Mr. Scott on the Subject, together with the Discussion thereof, and Independent Contributions on the Subject.

Reprinted from Vols. XXVIII–XXXI of the Transactions of the American Institute of Mining Engineers.

NEW YORK CITY:
PUBLISHED BY THE INSTITUTE
At the Office of the Secretary.
1902.

CONTENTS.

"The first four columns require no explanation. The fifth shows the point of the cord, expressed in decimal parts of it, at which the *Gradbogen* should be suspended in order to obtain a true reading, as shown in the third column.

"The values in the fifth column have been computed by Prof. Junge from readings made at the center and both ends of the cord, according to Lagrange's interpolation-formula. We agree with Prof. Junge that the point for the suspension of the *Gradbogen*, under the same conditions, should be removed from the center upward, in proportion to the length of the cord, which theory has also been verified by Borchers (see *Berg- u. Hüttenm. Zeit.*, No. 25, 1863); and it is to be pronounced an omission by Florian that in formulating his rule he took no account of this important fact. On the other hand, we take issue with Prof. Junge that he has not sufficiently emphasized the effect of the increasing vertical angle upon the correction to be made, to which Florian has attached the most importance. In a word, Florian says the *Gradbogen* should be suspended one decimal inch from the center for every degree of inclination; while Junge summarizes his experiments with the assertion that it should be suspended, on an average, 0.58 of the length of the cord from the lower end.

"To combine these, we must consider whether the absolute values given by each correspond. For the angle of 45° in Florian's rule, with the correction of 50 decimal inches, the values given by each are respectively as accurate as could be desired. By Junge's twenty-third experiment, in which the angle is 46° 42′, the distance of the suspension-point from the center is given at 0.098 of the length of the cord; that is, in this case, $4.67 \times .098 = 0.458$ Freiberg *Lachter*, or $0.458 \times 1.024 = 0.47$ Weimar *Klafter*. Now, according to Florian, the suspension-point should have been 0.52 Weimar *Klafter* from the center of the cord; but if we consider that Florian used a longer cord, as well as that the average values in the sixth column, twenty-third experiment, represent one of those cases in which the point of suspension has been given by Prof. Junge, no doubt, a little too low, we may safely say, as to Florian's correction-limit, that nothing better could be desired.

"Using Florian's rule, we find that by it, and on the basis of Junge's experiments, the best results are obtained if the number of degrees and fractions thereof, as read at the center of the cord, are multiplied by the factors 0.003 and 0.004, and to this result are added 0.50. Figures obtained by this calculation are shown in columns 7 and 9. In columns 8 and 10 the comparative average values show that up to an inclination of 15° the factor 0.004, and with greater angles the factor 0.003, give the best results. Therefore, to read the vertical angle as accurately as possible, the *Gradbogen* should be suspended toward the higher end of the cord at a distance from the center obtained by multiplying the length of the cord, at angles up to about 15°, by 0.004 for each degree, and for larger angles by 0.003.

"It might be said that, in the deduction of this rule, the weight of the *Gradbogen* and the tension in the cord have not been considered. But when two systems of experiments like those cited, made at different times and places, and therefore surely under very different circumstances, gave such similar results without considering the above factors, we are hardly justified in taking them into account."

P. & R. WITTSTOCK* (communication to the author): We read in the *Engineering and Mining Journal* of January 16, 1897, and

* Mathematical instrument-makers, Plan-ufer 92, Berlin, Germany.

in the *Colliery Engineer* for February, 1897, descriptions of Mr. Scott's new mine tachymeter, which so recommended itself to us that we at once undertook its construction. In the meantime we have read Mr. Scott's paper, and have been in correspondence with that gentleman, and he has given us several ideas concerning this latest type described below; but we are particularly indebted to him for suggestions concerning the edge graduation for the vertical circle and the method of mounting a compass over the telescope, to take the place of the striding compass, which has not yet ceased to be popular in this country.

The extension tripod is made of seasoned maple, is of a light pattern, and closes up to three feet in length. The upper ends of the legs have wooden tongues inserted to prevent splitting. The tripod head is cast in one piece, and the connection of the instrument is established by a strong screw-thread of a few turns. This is as simple and effective as is possible, and possesses the advantage of never getting out of order.

The engineer, who has to work occasionally in a chilly atmosphere, will appreciate the unusual size of the four leveling screws. Under any conditions they are a great advantage in connection with instruments having very sensitive levels.

The compound vertical axes of the instrument are turned with the greatest possible precision, are fitted to each other with exacting care, and are of such strength as to give the whole instrument an uncommon rigidity and stability.

Both horizontal and vertical circles are divided on solid silver. The figuring on the horizontal circle runs consecutively from 0 toward the right around to 359° in a single row. That permits the opposite verniers, marked I and II, to be also single. This is the only safe, simple and systematic method, as the angles are always read from left to right, no matter what the size. There is never any danger of reading the wrong set of figures or the wrong vernier, as might happen with the double row of figures and double verniers, which were devised in the mistaken idea of being better adapted to suit all conditions. A special feature of our graduation is its remarkable exactness, which cannot fail to give satisfaction to the most critical and scrutinizing engineer. The figures are placed unusually close to the edge of the graduation, which fact we feel will be much appreciated by those who have experienced the difficulty of reading the point of contact with long lines and distant figures.

The cylindrical ends of the horizontal axis rest in the Y bearings of the U-shaped aluminum standards. The bearings, one of them adjustable, have the usual covers, through which are inserted the friction screws with ivory points. The vertical pillars terminate in screw-threads, just like the extremities of the horizontal axes, to which the interchangeable auxiliary telescope and its counterpoise weight may be attached, and so revolved to any desired position. The pillars are made with large openings, and of such a shape (see Fig. 89) as to interfere as little as possible with the aiming of the main telescope.

Both telescopes are focused by a rack and pinion movement, and protected by a dust-guard slide that is not cut out to provide for the objective-end of the telescope bubble tube, as is very often done. We have crowded the telescope bubble as near to the ocular-end as possible (see Fig. 87), in order to accomplish this desirable result. In this position it is equally effective, and, besides, is more easily observed than when suspended exactly below the middle of the main telescope. All the optical parts are only of the first quality, and the magnifying powers, as stated in the following table, secure for the field of view an incomparable brilliancy; but, whenever we are called upon to employ a power one-third higher, nothing but satisfactory results are still obtained.

On one end of the horizontal axis is the vertical circle; on the other the gradienter screw, which also serves as the vertical clamp-and-tangent-screw. The beveled head is divided into 50 spaces, each of which corresponds to $\frac{1}{100}$ foot at a distance of 100 feet; or if the screw be moved through two entire revolutions, the horizontal hair of the diaphragm will travel vertically over the space of 1 foot, 100 feet away.

The figures placed on the vertical circle divide it into quadrants running each way, up and down, from the central zero-line. In this way an angle of elevation or depression may be read with the main telescope in either a normal or a reversed position. Mr. Scott says, in his estimation it is better to check a vertical angle by reading it in this way than to employ opposite verniers, which increase the risk of ruining the graduations by the grit that is deposited from percolating waters. For this reason one double vernier is provided; and it is now placed in a more convenient position for reading, as will appear shortly.

Table of Dimensions.

Sizes.	A.	B–1.	B–2.	C.
Horizontal circle, ...	4 in.	4½ in.	5 in.	5 in.
Vertical circle, ...	4 in.	4½ in.	4½ in.	5 in.
Main telescope (inverting), .	7½ in.	8 in.	8 in.	9½ in.
Magnifying power, ...	18 diam.	20 diam.	20 diam.	22 diam.
Object glass, ...	1⅛ in.	1⅛ in.	1⅛ in.	1¼ in.
Can be focused, ...	down to 3 feet.			
Auxiliary telescope (inverting),	5½ in.	6 in.	6 in.	6½ in.
Magnifying power, ...	12 diam.	14 diam.	14 diam.	16 diam.
Object glass, ...	¾ in.	⅞ in.	⅞ in.	1⅛ in.
Can be focused, ...	down to 3 feet.			
Length of needle, compass attachment, ...	3¼ in.	3¾ in.	3¾ in.	4½ in.
Weight of instrument with attachments, ...	3.58 kg.*	......	3.95 kg.†	......

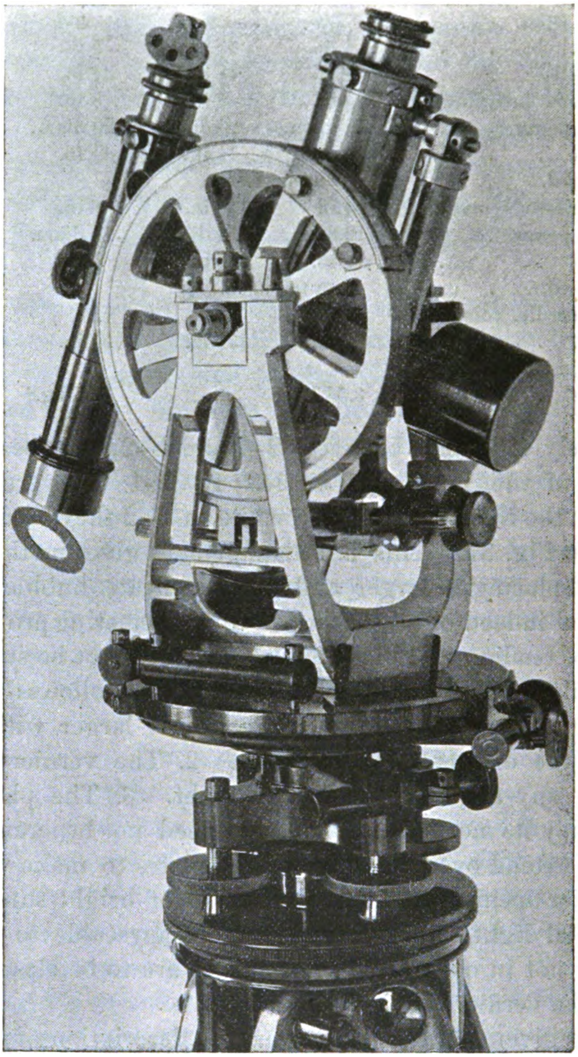
The only difference between B–1 and B–2, as appears, is in the size of the horizontal circle. In B–1 the verniers are placed on the top, as in Fig 86; while in B–2 they occur at the side, as in Fig. 87. This last arrangement gives us the opportunity of placing a larger and more delicate bubble on the plates, and indeed of presenting to the engineering profession a method of reading and illumination which cannot be surpassed. Its special advantages may be enumerated as follows: 1. It is obvious that the size of the graduation is larger without increasing the diameter of the plates. 2. The verniers can be placed at any angle to the line of sight. 3. The plate level may occupy its normal position, and need not be cramped, or made to extend over the edge of the plates to make room for the vernier-openings. 4. The diffusion of bright sunlight, or of artificial light underground, is more agreeable to the eye. 5. When not in use the reflector-shades are to be closed up, to protect the vernier.

Having given above a brief general description of the four types as we make them, we desire now to dwell in detail upon some of the more characteristic features of this new design, which we do not hesitate to say gives us the right and privilege

* 7.89 lbs. † 8.71 lbs.

to denominate Scott's mine tachymeter the most universally convenient and complete instrument ever constructed for mines.

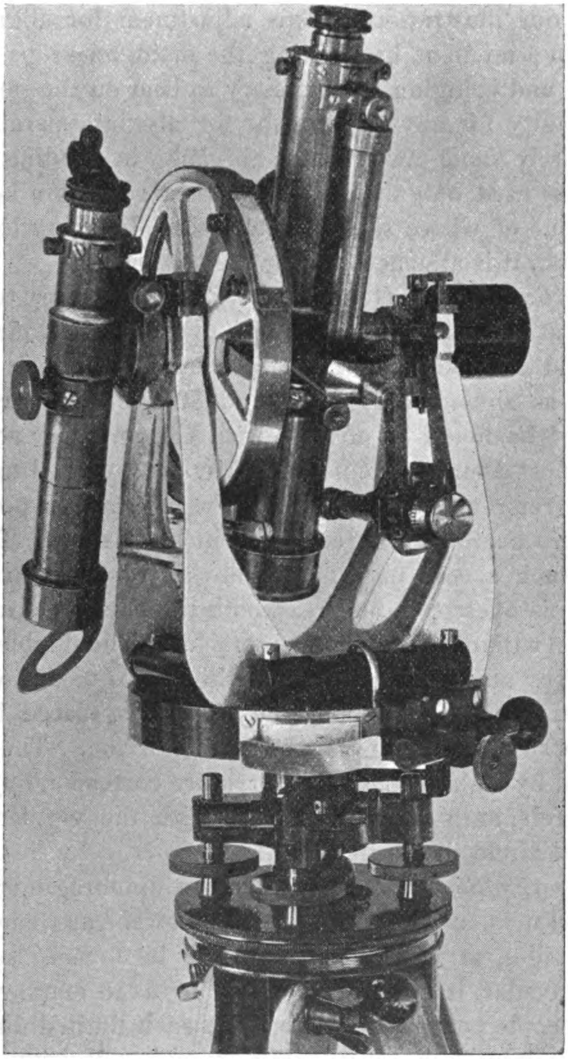
FIG. 86.



Scott's Mine Tachymeter, P. & R. Wittstock's Size A (4 in.).

The Interchangeable Auxiliary Telescope.—In America the auxiliary telescope has been in use for a great many years, but never before has it been possible to use it in more than one position as the case might require. But here is an appliance

FIG. 87.



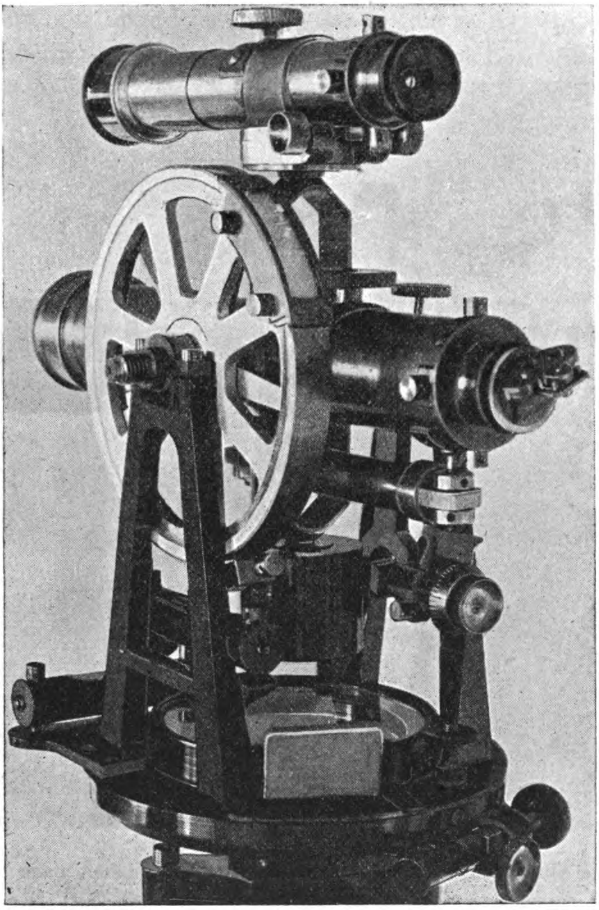
Scott's Mine Tachymeter, P. & R. Wittstock's Size B-2 (5 in.).

which can be used on the top, if a horizontal angle is to be read while the telescope is steeply inclined, or at the side, if an unusually steep vertical angle is to be read; and in each case with positively no correction for eccentricity. It may be attached as desired to any one of the four radial arms of the main telescope, and ranged very quickly and accurately into perfect adjustment with it by two opposing thumb-screws, as shown in all of our illustrations. This adjustment for alignment is secured in a moment by sighting the main telescope at a distant light and bringing the auxiliary to bear on the same light. The necessity for any adjustment for absolute parallelism is now entirely done away with; because in reading vertical angles it is used only at the side, and in reading a horizontal angle at one of whose sides the telescope dips very low below the horizon, it is attached only at the top.

The Vertical Circle.—Generally it will be customary to use the auxiliary at the right side, opposite to the vertical circle; but if it should ever be found more convenient to attach it to the left side, as shown in Figs. 87 and 89, the edge graduation will never be found to conflict with the auxiliary so placed. But the most desirable point which Mr. Scott wished to develop here has reference to occupying a very cramped position in surveying a narrow and precipitous inclined shaft. The engineer in such a case may now make an observation through either of his telescopes, and read both the horizontal and vertical circles without moving in his tracks! The double vernier is carried by an aluminum frame, with ample means of adjustment, that protects the whole circle, and is placed in a convenient position at about 45° above the horizon. The opening is covered by a glass plate of a curvature corresponding to that of the circle, as is indeed the case with the verniers of the horizontal circle shown in Fig. 87.

Disappearing Stadia Webs.—When the diaphragm is made of extra thickness, and the cross and stadia-webs are mounted on opposite sides, so that each group may be focused separately with the ocular, it seems impossible to us to employ equally high telescopic powers satisfactorily in such limited dimensions as are usual in the ordinary size surveying instruments. If, for instance, the focus of the objective is 9 inches, and the telescope of 20 diameters power, then the focus of the first lens in the ocular will be $\frac{9 \times 2}{20} = \frac{9}{10}$ inch, and the distance of the image from the first lens $\frac{9}{10 \times 10} = \frac{9}{100}$ inch. Consequently the thickness of the diaphragm must not be greater than $\frac{8}{100}$ inch, in order to leave a little space between the eye-piece and

Fig. 88.

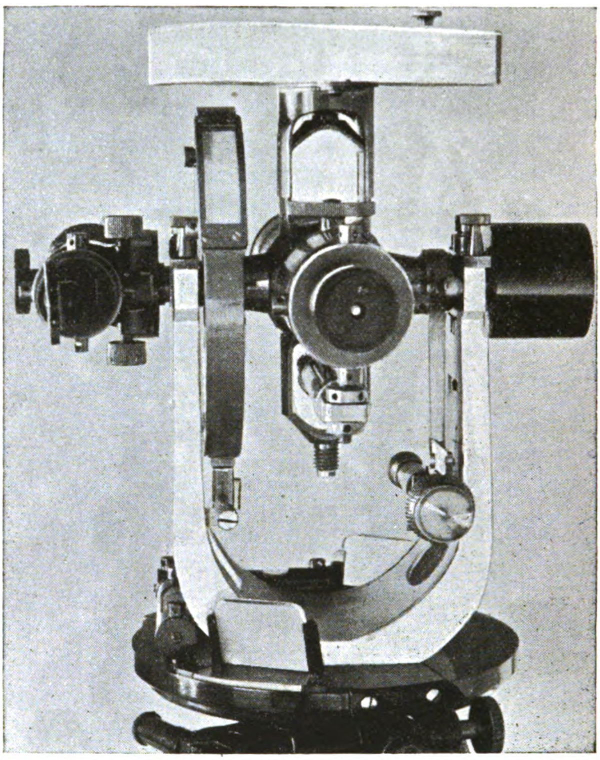


Scott's Tachymeter with Fixed Compass, made by P. & R. Wittstock.

diaphragm when the webs on the further side are in focus. Now, where is the room that should be allowed to suit the varying requirements of the eyes of different operators? Further than this, in such a case the webs that are out of focus are not far enough away to be entirely invisible, but blur the field of view; and, besides, every time it is desirable to change from one set of webs to the other it is necessary to re-focus not only the ocular, but also the objective.

Our construction provides for the usual worm-thread focusing arrangement for the ocular, with ample play to suit the requirements of different eyes. The cross-webs are also mounted

Fig. 89.



Detachable Aluminum Compass, on Scott's Mine Tachymeter, made by P. & R. Wittstock.

in the usual manner on a diaphragm of the usual form and size. It has, however, a tube-like prolongation toward the objective, in which a second diaphragm moves that carries the stadia-webs. By moving this second diaphragm backward or forward, the stadia-webs are brought into the field of view, or moved entirely out of it. The screws which govern this motion from the outside are of ample capacity to do this effectively. It will be understood that by this arrangement the cross-webs are never out of focus, and the adjustment of the line of collimation is, therefore, never impaired; since the eye-piece and object-glass always remain untouched.

Luminous Levels.—We have experimented considerably with luminous levels, and believe we have the honor to be the first house actually to introduce them as suggested by Mr. Scott. We have found that when exposed to a diffused dry light the luminous substance will act longest and best, and in the dark the divisions in the glass and the bubble itself appear quite distinct. When the action becomes weaker, and the luminosity fainter, it is with some difficulty that the bubble can be detected even with a magnifier; but the efficiency in this respect is restored by burning a strip of magnesium before the bubbles. However, it is only on rare occasions that this novelty will be an actual necessity, as Mr. Scott says, and no doubt what we have accomplished will amply suit all requirements.

The Compass Attachment.—To adapt this instrument to all the requirements as demanded still in Germany, England, and elsewhere, a circular compass-box, made of aluminum, is mounted on the upper vertical pillar, in the same way as the auxiliary telescope is attached. Most mine surveyors will have established near their works a true meridian determined by astronomical observation. The instrument should be set up at one end of this line, and, when the other is sighted through the telescope, the needle is brought to read upon the north point by means of the opposing milled-head screws below. By this same means any desired declination can be set off. As the compass-box is very light, weighing only .15 kg., or 5 ounces, there is no reason why observations through the main telescope should not be made at any considerable inclination with the compass still attached and the needle clamped; but before the needle is read, of course, the telescope must be brought back to a horizontal position. We also make a non-adjustable style, as shown in Fig. 89, which can be very easily and exactly attached, and can be carried in the pocket. Of course, there is no limit to the length of needle that may be used in this model, but we recommend those suggested in the table.